Preliminary findings indicate a positive breakthrough in the use of NMES in dysphagia rehabilitation. *(photo/courtesy Bowie Speech & Hearing, Inc./Bowie Rehabilitation Services)*

Promoting Laryngeal Elevation with E-Stim

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A COMMONLY ENCOUNTERED functional abnormality in dysphagia is a decrease in laryngeal elevation, which is important in the elongation of the pharyngeal-esophageal sphincter (PES) and assistance with epiglottic closure.[1]

Using a team approach, we have located an area that can be safely and efficiently stimulated to promote laryngeal elevation. This was achieved with no required comprehension or understanding of specific strategies or techniques by our subjects at Bowie Speech and Hearing, Inc., in Fort Worth, Texas. The results of our study support our hypothesis that significant laryngeal elevation can be reproduced with only the use of neuromuscular electrical stimulation (NMES) to the correct motor point.

Paired mylohyoid, geniohyoid and anterior belly of the digastric muscles are primarily responsible for anterior and superior movement of the hyoid bone during a swallow. This movement of the hyoid and laryngeal elevation is vital in preventing aspiration. The superior movement of the larynx helps bring the airway safely away from the path of the bolus. In dysphagia rehabilitation, techniques used to accentuate and prolong laryngeal elevation often are used as indirect dysphagia treatment. These techniques are based on the anatomical relationship of the hyoid, larynx and cricopharyngeal region.

There has been a growing interest regarding the use of NMES with dysphagia rehabilitation programs. Previous studies used NMES with an invasive approach to electrode placement.[2] The concepts of electrical stimulation typically are taught in the coursework for physical therapy.

Using a team approach, a physical therapist set the parameters for the electrical stimulation, and a speech-language pathologist analyzed the laryngeal elevation. The placement of the electrodes was superficial, and the data-measuring instrument was noninvasive.

An area between the oral cavity and the circumference of the neck was located to decrease the risk of adverse effects as listed by the U.S. Food and Drug Administration (FDA). These adverse effects include closure of the airway due to placement of the electrodes over the neck or mouth. The physical therapist and speech-language pathologists in this study can respond positively to each discipline's code of ethics and standards regarding application of NMES.

This stimulation can be used as an adjunct in the clinical treatment of a variety of neuromuscular and musculoskeletal problems provided the peripheral nervous system is intact. NMES has been reported to be used to increase strength and range of motion, facilitate weak contractions due to upper-motor neuron lesions or disuse atrophy, and re-educate muscles.[3,4,5,6,7]

Until recently, not many instruments or screening techniques have been available to diagnose oropharyngeal dysphagia or measure treatment effectiveness. However, the Computerized Laryngeal Analyzer (CLA)[8] measures the biomechanical movement of the anatomical structures associated with swallowing.

This instrument is approved by the FDA for use in the diagnosis and treatment of swallowing disorders using piezoelectric measurements. The CLA makes use of a thin film piezoelectric transducer, software, and a high-speed computer to provide on-line and real-time display of the laryngeal movements associated with a swallow.

This technology is non-invasive, which increases the population and time an assessment/treatment can be utilized. It measures the biomechanical movements during the swallow and automatically calculates and displays the duration of laryngeal motion. This allows the clinician to record the swallow pattern, intensity and timing, with these recordings giving a quantitative value to be documented.

The CLA graph displays superior and anterior planes of movement upward and inferior and posterior planes of movement downward. Wave forms on the CLA are generated by planes of movement of the larynx and the activity of extrinsic laryngeal muscles during the swallow. These movements are demonstrated, in sequence, from initial movement through the swallow pattern or stimulation trial.

A graph of the CLA recording is provided in Figure 1 (see page 26). Change on the y-axis demonstrates the degree of pressure change or range of motion of the larynx, and the onset and duration of the laryngeal activity is demonstrated in real-time on the x-axis. The use of piezoelectric measurement of the above biomechanical movements of the swallow has been reported by several investigators.[9,10,11,12,13]

To use NMES on the bellies of the anterior digastric, mylohyoid and other suprahyoidal musculature to promote laryngeal elevation while recording it using the CLA, the piezoelectric transducer first is attached to an individual's thyroid cartilage, and three dry swallows are monitored by the CLA. Two moveable electrodes connected to a neuromuscular electrical stimulator now are placed over the region of each belly of the anterior digastric and mylohyoid muscles. The electrodes are housed in plastic caps, with a moist sponge of water conducting the current to the muscles. The individual is asked to hold the NMES unit while pressing the constant stimulation (CS) button and increasing the intensity until a vibration is felt.

The physical therapist moves the electrodes on the muscle until a motor point is found and visual tetanizing contraction is observed. A motor point is where a motor nerve enters the muscle it innervates.[11] To achieve a visible contraction, the individual may need to increase the intensity. If the intensity becomes uncomfortable without visible contraction, the electrodes may be over a sensory nerve point. Once the motor points are found, the individual will increase the intensity to maximum tolerance and release the CS button.

The physical therapist then takes the NMES unit from the subject and stimulates the area three times for approximately four seconds each, while the subject holds the electrodes and maintains a neutral head and neck position. Each subject is instructed to look straight ahead and not assist or resist the contraction in any way during each four-second trial.

There are approximately 15 to 30 seconds rest time between stimulation trials while the speech-language pathologist assesses the elevation in mV on the CLA. The parameters include a rate of 30 Hz with a preset pulse width, a .4-second ramp, and a symmetrical biphasic waveform using a NMES unit.[14]

The rationale for these parameters is as follows:

- stimulating the anterior digastric for being the most superficial suprahyoidal muscle, its origin on the inferior border of the mandible and its insertion at the cornu of the hyoid, acting to elevate and pull the hyoid anteriorly;
- stimulation overflow to the mylohyoid for its origin on the mylohyoid line of the mandible and its insertion at the body of the hyoid, acting to elevate the hyoid and the tongue;[15]
- a pulse rate of 30 Hz to produce a tetanizing muscle contraction with minimal muscle fatigue; [16]
- a .4-second ramp to allow for rise in intensity; and
- symmetrical biphasic waveform to efficiently stimulate both electrodes. [17]

A CLA graph of a normal subject performing an exercise of accentuating and prolonging laryngeal elevation (see Figure 2 on page 26) shows the movement during the swallow, at which time the larynx is held in the upward position. Therefore, the graphic display or line returns near the 0 mV level secondary to no change in pressure with noticed increased tension during the exercise duration. The line demonstrates the new change in pressure during the release of laryngeal elevation, and a new peak is demonstrated on the CLA graph.

The CLA was used to document the effectiveness of electrical stimulation in promoting laryngeal elevation without a volitional response from the subject (see Figure 3 on page 26).

After the .4-second ramp of stimulation, an initial recruitment of the platysma creates a downward motion of the larynx. The platysma—a broad, thin layer of muscle situated on each side of the neck immediately under the superficial fascia—draws the lower lip and corner of the mouth to the side and down and, when moved forcefully, expands the neck and draws the skin upward.[12]

After the .4-second ramp to the one-second frame on the CLA graph, there is increased recruitment of the platysma and suprahyoidal musculature, which then elevates the larynx. This pressure is maintained with some fasciculations until the stimulation is released at the four-second frame on the CLA graph. This shows a significant change in pressure from the release of the elevated larynx. Each subject was measured at a gain of two on channel 1 on the CLA interface unit during dry swallow measurement and stimulation trials.

To stimulate the anterior digastric and mylohyoid muscles, the current has to pass through the skin/fascia layer and platysma. The electrical current passes through these layers to the anterior digastric and mylohyoid musculature and may overflow into other musculature.

The benefits of stimulating the anterior digastric and mylohyoid muscles are that they voluntarily assist the end of the oral stage through the elevation of the tongue via the mylohyoid and contract during the pharyngeal stage, assisting elevation of the larynx via the anterior digastric and mylohyoid.[12]

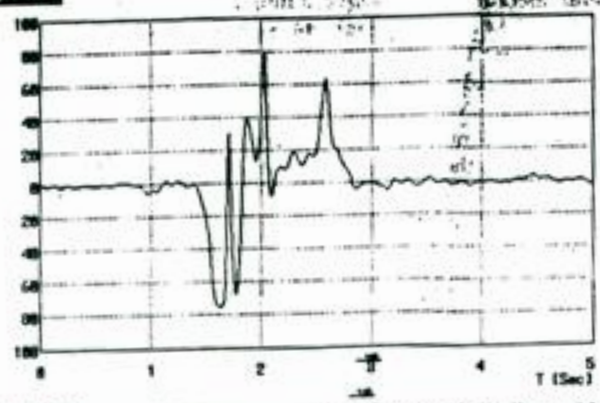
The proper placement of the two electrodes over the motor points of each belly of the anterior digastric and/or mylohyoid muscles elicited measurable movement of the larynx (see Table 1 on page 27). The movement recorded averaged a mean of 40.04 mV on 25 individuals through use of NMES only.

The participating individuals recorded a mean of 52.6 mV on a normal dry swallow, with consistent wave forms. These two results denote that NMES elicited 76 percent of the mean laryngeal elevation of the normal swallows. The effective initiation of movement achieved through electrical stimulation recorded on the CLA resembles a pattern that demonstrates laryngeal elevation while maintaining stimulation for four seconds (see Figures 2 and 3).

Movement of the larynx was displayed ▷

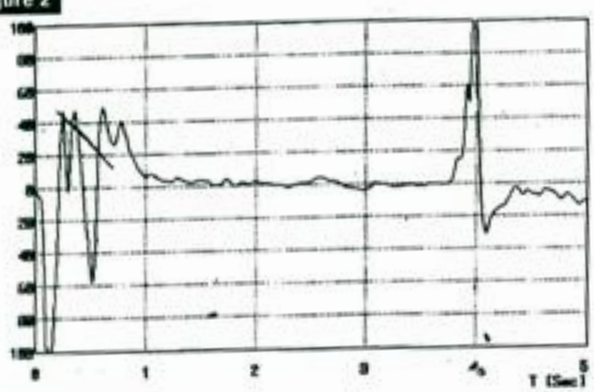
Evaluation - Instructed Dry Swallow

Figure 1



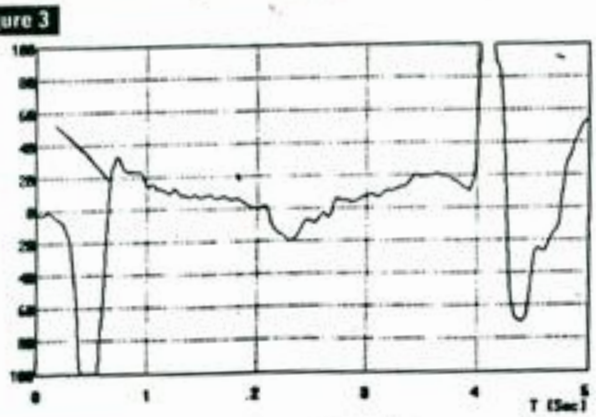
CLA—At 1.34 seconds, initiation of the oropharyngeal swallow with a duration of 1.48 seconds; note the release of the laryngeal elevation at 2.82 seconds. Normal swallow wave form indicated on the CLA graph.

Figure 2



At .09 seconds, initiation of oral phase. Pharyngeal swallow with prolonged laryngeal elevation initiated at .75 seconds and held to 4.0 seconds, at which time the CLA graph depicts the release of the laryngeal elevation achieved during the swallow.

Figure 3



Stimulation of the suprahyoidal musculature initiated at .17 seconds that initiated the elevation of the larynx, which lasted until the 3.82-second [illegible] the CLA graph, at which time the release of the larynx is indi-[illegible] from the termination of the NMES. *(graphs/courtesy Bowie Speech & Hearing, Inc./Bowie Rehabilitation Services)*

at the initiation of the stimulation. During the stimulation, the larynx is held in position; therefore, there are no changes in pressure from the thyroid cartilage and the piezoelectric transducer. This is demonstrated by the return of the graphic display to the 0 mV level.

At the stimulation release, there is a new change in pressure from the returning of the larynx from the elevated position. It is significant that a sustained elevation was achieved by stimulation only (no swallow initiation) and required no understanding or mastering of a special instruction or technique. Patterns and mV were comparable to each individual's normal laryngeal elevation pattern and the amount of intensity tolerated (intensity range 15-25).

Our future intention is to continue the use of this process using videofluoroscopy to support laryngeal elevation and to investigate epiglottic closure and esophageal sphincter elongation. Together as an allied health care team we can greatly assist in the future of dysphagia rehabilitation. An eventual study of dysphagia patients is needed to document this process for its effectiveness.

The findings from this preliminary report indicate a positive breakthrough in the use of NMES in dysphagia rehabilitation while using an interdisciplinary team including a physical therapist and speech-language pathologist. Although this was only the preliminary report preceding an actual scientific study, the results were encouraging.

Research currently is under way to assess the use of NMES with dysphagia following CVA.

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Table 1 - Results

Subject	Intensity of Stimulation (milliamps)	Swallow without Stimulation (millivolts)	Stimulation Only	Average
29 yo M	23 mA	100mV	68.3mV	68.3%
28 yo F	21 mA	28.3mV	30.9mV	109.1%
42 yo M	25 mA	56.3mV	64.3mV	114.2%
36 yo F	16 mA	36.6mV	30.6mV	83.6%
46 yo F	20 mA	27.3mV	55.3mV	202%
42 yo F	16 mA	22.3mV	24mV	107.6%
29 yo F	21 mA	27.3mV	36.3mV	133%
26 yo F	15 mA	100mV	20mV	20%
39 yo M	18 mA	100mV	32.3mV	32.3%
42 yo F	15 mA	13mV	15mV	115%
49 yo F	21 mA	16.3mV	27mV	165.6%
35 yo F	20 mA	99mV	33.3mV	33.6%
28 yo M	18 mA	88mV	28mV	31.8%
31 yo M	15 mA	22.3mV	11mV	49.3%
33 yo M	17 mA	45.3mV	40.3mV	88.9%
31 yo M	24 mA	43.6mV	40mV	91.7%
31 yo M	18 mA	93mV	100mV	107.5%
32 yo M	20 mA	66.3mV	65mV	98%
21 yo F	19 mA	27.6mV	15mV	54.3%
30 yo M	14 mA	29.3mV	16.3mV	55.6%
30 yo M	20 mA	49.3mV	74.3mV	150.7%
45 yo F	15 mA	69.6mV	34.6mV	49.7%
32 yo M	21 mA	99mV	50mV	50.5%
33 yo M	16 mA	29.6mV	21.3mV	71.7%
38 yo F	20 mA	27.6mV	68mV	246.3%
Mean Age: 34.32				

Totals:

Average	18.72 mA	52.6mV	46.04mV	93.3%
Range	14-25 mA	13mV-100mV	11mV-100mV	20%-246.3%

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